The Impact of Graphing Calculators on Student Performance in Beginning Algebra: An Exploratory Study

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Abstract

The exploratory study, The Impact of Graphing Technology on Student Performance, focused on what students learned in algebra, how it was different for students with differential access to graphing calculators, the use of the technology on tasks of different cognitive demand, and whether the teachers' background and experience with graphing calculators might be related to student outcomes. The study considered two conditions: high quality professional development and high frequency calculator use on the part of the students and involved three different populations: 1) teachers who seldom or never used graphing calculators in their classrooms; 2) teachers who used graphing calculators in their classrooms but without a high degree of support and ongoing professional development; and 3) teachers with a high degree of support and ongoing professional development in the use of graphing calculators for instruction. Results indicate that access to and use of graphing calculators seems to increase achievement, achievement decreases for both users and nonusers of calculators as the cognitive demand of the tasks increases, and while the background and experience of the teachers seems to make a difference for the top 75 percent of the students, some students perform at very low levels with or without the technology.

The Impact of Graphing Calculators on Student Performance in Beginning Algebra: An Exploratory Study of Two Factors Affecting Learning[1]

Since graphing calculators became available in 1985, they have been part of mathematics instruction at the secondary level in a variety of forms. Questions about whether this technology is an effective tool in teaching and learning mathematics have fueled discussion and debate ever since (Penglase & Arnold, 1996; Ruthven, 1996; Wu, 1997). Some studies found that the technology supports learning (Ellington, 2003, 2006; Graham & Thomas, 2000; Hollar & Norwood, 1999; Khoju, Jaciw, & Muller, 2005; Schwarz & Hershkowitz, 1999), while others raised concerns that the use of handheld graphing technology supplants learning or leads to dependency (Dancis, 2004; Hennessy, Fung & Scanlon, 2001; Simonson & Dick, 1997).

THE STUDY

Several issues that emerged when reviewing the literature on handheld graphing technology (Burrill et al, 2002; Ellington, 2003) laid the foundations for this exploratory study, The Impact of Graphing Technology on Student Performance in Beginning Algebra. (1) Much of the research on the use of graphing technology in teaching and learning mathematics deals with mathematical content often taught in second year algebra, precalculus or calculus. Very few studies focused specifically on beginning algebra. (2) Some studies were based on short content units for which students were given the technology for that particular unit (Harskamp et al, 1998; Merriweather & Sharp, 1999). Van Streun and colleagues (2000), however, found that the technology made a difference for students only after a prolonged period of use but did not report the nature of student access. And while attention was paid to the attitudes and behaviors of teachers and students when using the technology, the preparation of the teachers to use the technology was rarely addressed. (3) In addition, questions have been raised about the nature of student learning when using handheld technology (for example, Tucker, 1999). Studies often report how students perform on multi-step tasks or on tasks that require a higher level of understanding (Graham & Thomas, 2000; Thompson & Senk, 2001). Keller, Russell and Thompson (1999) reported that college students using the TI-92 with the technology were able to better solve more complex problems. But in all of these studies, what defined tasks as higher level or cognitively complex was not always made explicit.

As a consequence of these issues, the exploratory study focused on what students learned in algebra, how it was different for students with differential access to graphing calculators, the use of the technology on tasks of different cognitive demand, and whether the teachers' background and experience with graphing calculators might be related to student outcomes. We looked at two factors in the context of the cognitive demand of

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tasks students were able to perform on pre-post tests. The first was the nature of student access to the technology, including use on homework and ownership. The second was the background and experience of the teachers.

We identified three different populations: 1) teachers who seldom or never used graphing calculators in their classrooms and had little or no professional development related to their usage; 2) teachers who used graphing calculators in their classrooms but without a high degree of support and ongoing professional development; and 3) teachers with a high degree of support and ongoing professional development in the use of graphing calculators for instruction.

Teachers in the third group were randomly selected from members of Teachers Teaching with Technology (T^3), a group of teachers supported by Texas Instruments Education Technology, who attend at least one two-day professional development meeting a year, receive the most recent products related to graphing calculators and their use, and have access to training on how to use these products. These teachers, in turn, conduct workshops and seminars around the United States on using graphing calculators in the teaching and learning of secondary mathematics. Groups 1 and 2 were selected by recommendations from mathematics supervisors or department chairs in districts comparable to the teachers from the random sample of T^3 teachers. Those making the recommendations were asked to select teachers who were recognized as good teachers and who had assumed some form of leadership role at the local or state level.

Data were collected on student and teacher background, experience, attitudes and beliefs about mathematics and about technology, and about school environment, curriculum, and modes of instruction

Students were given a pre-test to check the initial comparability of the classes and a post-test at the end of the course. All items on both tests were categorized in terms of their cognitive demand according to the mathematical task framework developed by Stein, Smith, Henningsen, and Silver (2000) with items rated as memorization, doing procedures without connections, doing procedures with connections and doing mathematics.

THE RESULTS

While the study was exploratory and many factors would have to be considered in the design of further investigations, the results suggest that access to handheld graphing technology in terms of ownership and for doing homework seems to affect what students are able to do, with the differences significant in both cases (Figure 1).

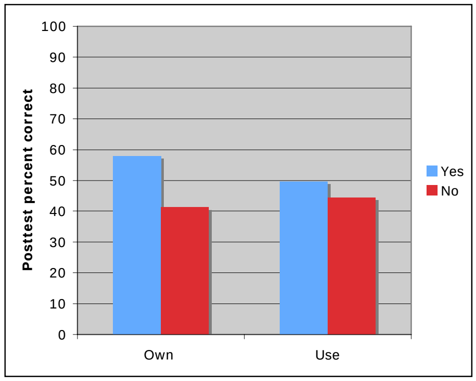

Figure 1. Posttest results related to student access to calculators

The results also suggest that the background of the teachers with the technology made a difference in student performance on the post-test (Figure 2), although in all groups there were students who performed poorly. (Note that the post-test scores were adjusted to account for class differences identified on the pre-test.) The percent correct for the T^3 instructors high frequency use group is significantly different from the non-T^3 high frequency use group ($p < 0.002$) and from the low frequency users ($p < 0.002$).

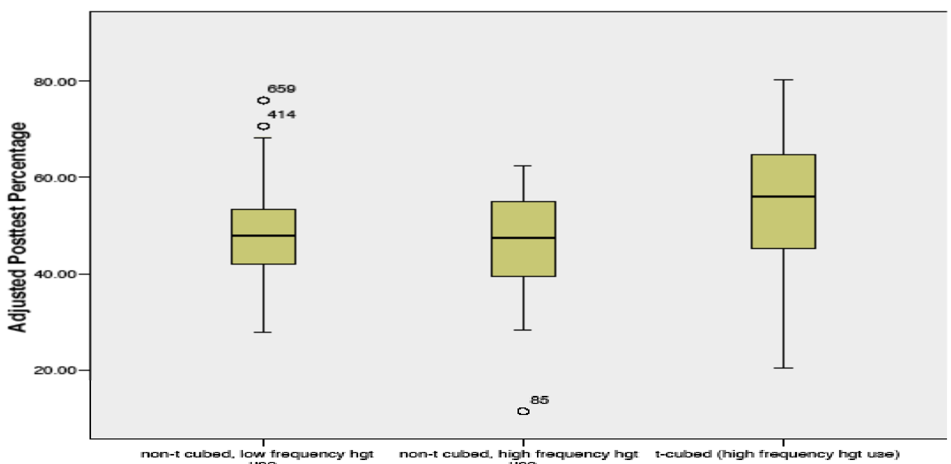

Figure 2. PD type and frequency of calculator use

Exploring student achievement in the context of the cognitive demand of the tasks provided indications that access (Figures 3 and 4) made a difference in performance on tasks that involved doing procedures and doing procedures with connections. Using adjusted posttest scores, the mean percent correct for items classified as procedures without connections was significantly different for the students of T^3 instructors (65.86 percent) than the students of teachers in group 1 and group 2 (57.99 with $p < 0.000$ and 55.48 with $p < 0.003$ respectively)). On items classified as procedures with connections, the mean percent correct for classes in the T^3 group (3), 58.57, was significantly higher than the means for the other two groups ($p < 0.01$ and $p < 0.02$). For doing mathematics items, the mean percent correct for all groups continued to decrease; students of non-T^3 teachers who used graphing calculators had a mean that was significantly higher than the other two groups ($p < .004$), and the mean percent correct for the T^3 instructors was the lowest of all three groups.

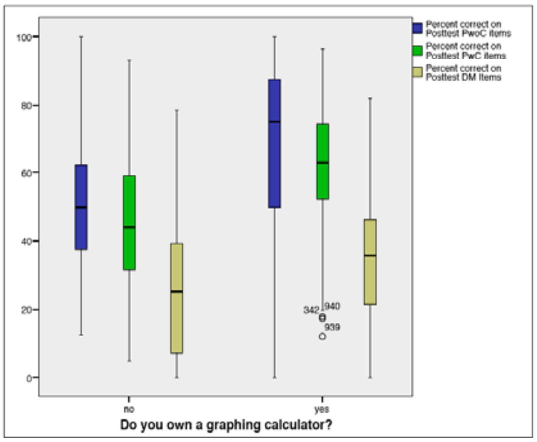

Figure 3. Calculator ownership by cognitive demand

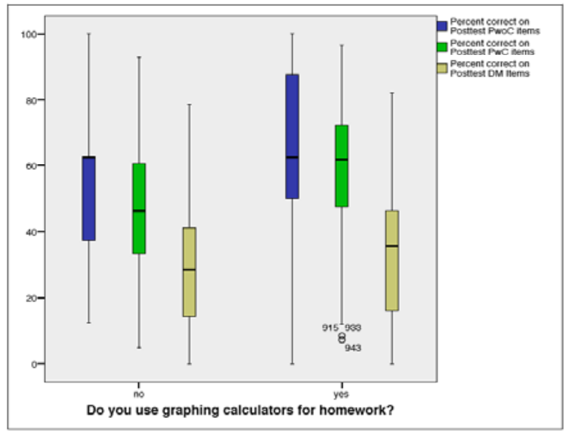

Figure 4. Calculator use on homework by cognitive demand

Figure 5 indicates that as the complexity of the tasks increased, student performance decreased, with students from all three groups of teachers performing poorly on the higher-level tasks classified as doing math by Stein and colleagues (2000).

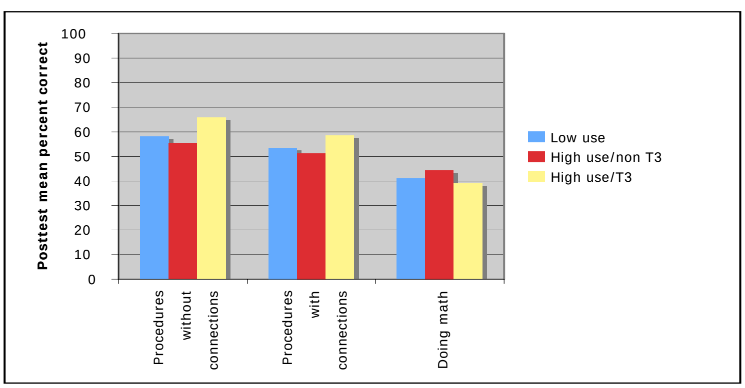

Figure 5. Adjusted posttest scores by professional development group and cognitive demand

CONCLUSION

Although exploratory, the study does point to several areas that would benefit from further investigation and research. The initial findings related to cognitive demand demonstrate the importance of looking for such differences in studies about the use and effectiveness of handheld technology. Just using grand means obscures what may be happening, which suggests more attention should be given to item-level analysis. The performance on tasks rated by cognitive demand in the study highlights fairly convincingly the need to make more significant progress in engaging all students with higher-level mathematics tasks and to think more carefully about how the technology is being used in creating and implementing challenging tasks. The study provides some evidence that access and use of handheld graphing technology should routinely be part of the learning process if they are to be effective tools for learning, which suggests that frequency (and quality) of use of the technology needs to be taken into account and not just the presence of the technology. The study also suggests the role of professional development in helping teachers understand how to maximize the potential of graphing calculators in teaching beginning algebra is important. Perhaps most importantly, however, looking only at significant gains in the differences between means hides indicators that these results do not seem to hold for students in the lower quartile, regardless of the professional development and experience of the teacher.

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